

Questions & Answers



MSI
MentalogicSystems Inc.TM

Fuzzy technology for embedded control

The bottom line with fuzzy logic, is reduced time to market, lower-cost of development, and improved system performance

Fuzzy logic technology is progressively penetrating the industrial control market. This new emerging technology has been successful in providing intelligent, yet low cost, solutions to industry. Fuzzy logic can be applied in the control of a variety of systems ranging from home appliances to sophisticated processes. The annual compound growth of fuzzy logic technology product sales is estimated at 75%.

Mentalogic Systems Inc. (MSI) specializes in the design and development of **fuzzy** technology systems, provide application solutions for embedded and industrial process controls: MSI is currently on the leading edge of this technology. The Company has developed the **next generation** of fuzzy logic microcontroller chips, development tools and systems, which form the basis of cost effective fuzzy control applications.

This brochure answers engineering questions about fuzzy logic technology and highlights the advanced developments achieved by MSI that makes its fuzzy technology easy, powerful and low cost to apply. Our goal is to convince you that our fuzzy technology will provide your company with the cost effective solutions for your specific applications.

Should you need more information about MSI fuzzy logic technology, about MSI products and services, or a particular application, please complete the card insert and send it to MSI, or contact us directly at (905) 940-6756.

Q1. What is Fuzzy Logic?

Fuzzy Logic is an Artificial Intelligence based technology, initially developed by Professor Lotfi Zadeh of the University of California at Berkeley approximately twenty years ago. Fuzzy logic is designed to **simulate human thinking** in computer programs and microprocessor chips to improve the performance in decision making and control applications.

Fuzzy logic provides a **reasoning algorithm** which simulates human thinking through the use of **expert knowledge**. This knowledge base usually contains imprecise and fuzzy statements such as: **Hot, Cold, High Speed, Low Pressure, Short Duration**, etc.

Fuzzy logic enables computers to understand two kinds of expert knowledge:

Interpretation Knowledge

Fuzzy logic uses the so called membership function (**MF**) distribution to interpret and quantify such fuzzy terms as: **Low, Medium, Hot, Cold**, etc. Figure (1) gives an example of the MF distribution to interpret the meaning of **Low, Medium, High** and **Very High** as declared by an expert to define a process variable, **Motor Speed**. The motor speed varies over the range 0-1000 RPM.

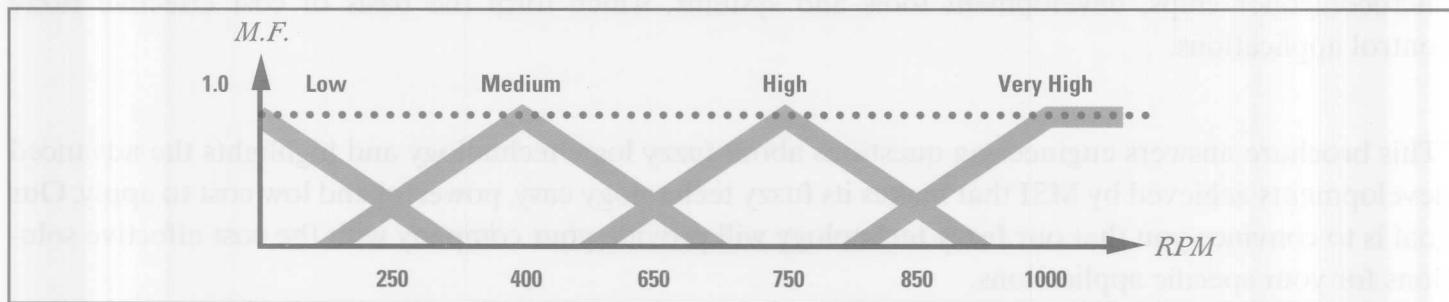


Figure 1. The MF Distribution

The Expert Rules

This knowledge conceives the expert “**IF ... THEN**” fuzzy rules. Each rule specifies a decision declared in the “**THEN**” part of the rule and the pre-text to this decision is declared in the “**IF**” part of the rule.

An example of a fuzzy rule is :

IF temperature is High then Fan Speed is Very High

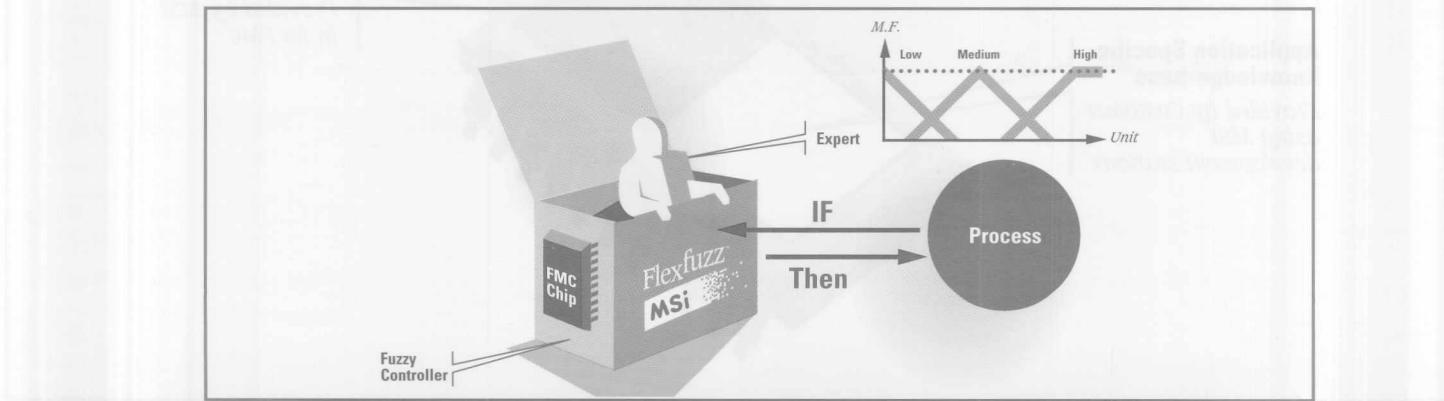
A fuzzy controller is a system which uses the fuzzy reasoning knowledge (the expert rules and MF distributions) to simulate the expert knowledge and to provide intelligent decision making and optimum control.

Fuzzy controllers are offered in the form of controller boards hosting fuzzy microcontroller chips (FMC) or ASIC chips. These microcontroller chips contain the fuzzy controller reasoning machine and memory to allocate the application specific knowledge base.

A Fuzzy controller consists of the **Reasoning Machine** and the **Knowledge base**. Our reasoning machine provides a universal and optimum control algorithm for all applications. The knowledge base hosts the expert rules and MF which are application specific. Two applications such as washing machines and air conditioning systems will require two different knowledge bases even though the fuzzy controller utilizes the same reasoning machine to control both systems.

The fuzzy knowledge base is usually generated and tuned manually by experts, or alternatively by the use of MSI's new fuzzy controller development system (FCDS) that incorporates **automatic knowledge base generation and tuning systems**.

Presently, the most popular use of fuzzy controllers is in embedded control applications (home appliances, automotive, equipment and machine control). Fuzzy controllers are currently penetrating the process industry to replace the PID controllers, MSI provides products to develop applications for the embedded and process control applications.





Q3. What is a Fuzzy Microcontroller Chip?

A Fuzzy Microcontroller chip (FMC) is a microcontroller device programmed with the fuzzy reasoning machine. It can be easily converted into a fuzzy controller system by providing the application specific knowledge base (the expert rules and MF) using, an engineer-friendly, Fuzzy Controller Development Systems (FCDS).

The anatomy of the fuzzy microcontroller chip is shown on Figure (2). The chip consists of two parts: the fuzzy controller reasoning machine (the reasoning brain) and the knowledge base part (the memory to store the fuzzy rules and MF).

The fuzzy microcontroller chip, in fact, simulates a human brain in its structure and functionality. Humans apply the same logical principles (the fuzzy reasoning machine) when driving cars or making business decisions, but employ different expertise (the application specific knowledge base) for each application.

MSI provides various fuzzy microcontroller chips (4, 8, and 16 bit). MSI also provides a set of advanced application development systems to make fuzzy controller development an easy exercise for control engineers.

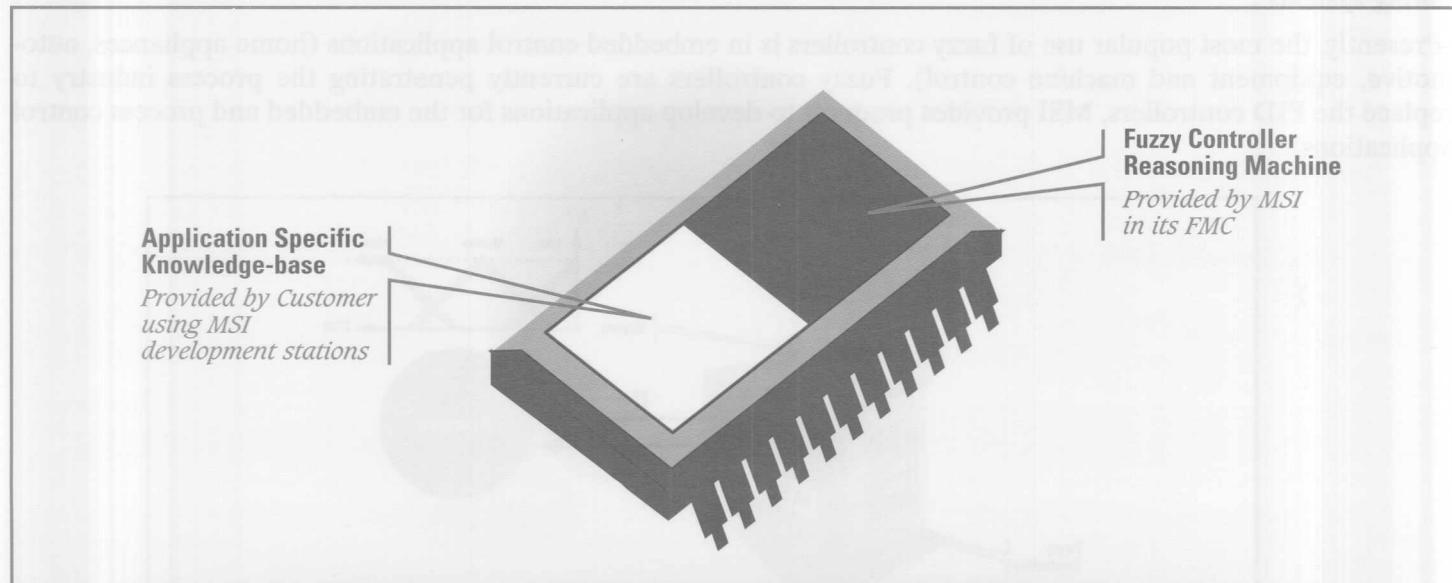


Figure 2. The Fuzzy Microcontroller Chip (FMC)



Q4. How Do I Customize a Fuzzy Microcontroller Chip For a Particular Application?

The customization of the FMC to suit a particular application is relatively easy and can be done directly by you. All you need to do is to select a microcontroller which will suit your application and order the **MSI Fuzzy Controller Development Station (FCDS)** to start the development of the fuzzy controller. The FCDS incorporates a set of FMC evaluation boards, and user-friendly CASE tools. MSI provides three kinds of these systems: **QuickFuzz** (for manual tuning of fuzzy knowledge base) **AutoFuzz** (for automatic tuning of fuzzy knowledge base) or **MultiFuzz** (for advanced multiple knowledge base fuzzy controller design). All these systems run on a PC using MS Windows. The **FCDS** helps you to develop the application specific knowledge base and to test the fuzzy controller performance on line, directly on your application.

Figure (3) shows the development environment using MSI FCDS.

The Customization of the fuzzy controller for a particular application using the FCDS consists of three steps:

1. The user works with **QuickFuzz** and **AutoFuzz** to develop the application specific knowledge base and to test the fuzzy controller performance (usually takes a few days).
2. Next, the user develops the non-fuzzy functionality using a set of FMC evaluation tools and system software suited for a particular FMC.
3. Finally, the user validates the performance of the customized FMC and passes the chip to the host board for mass production.

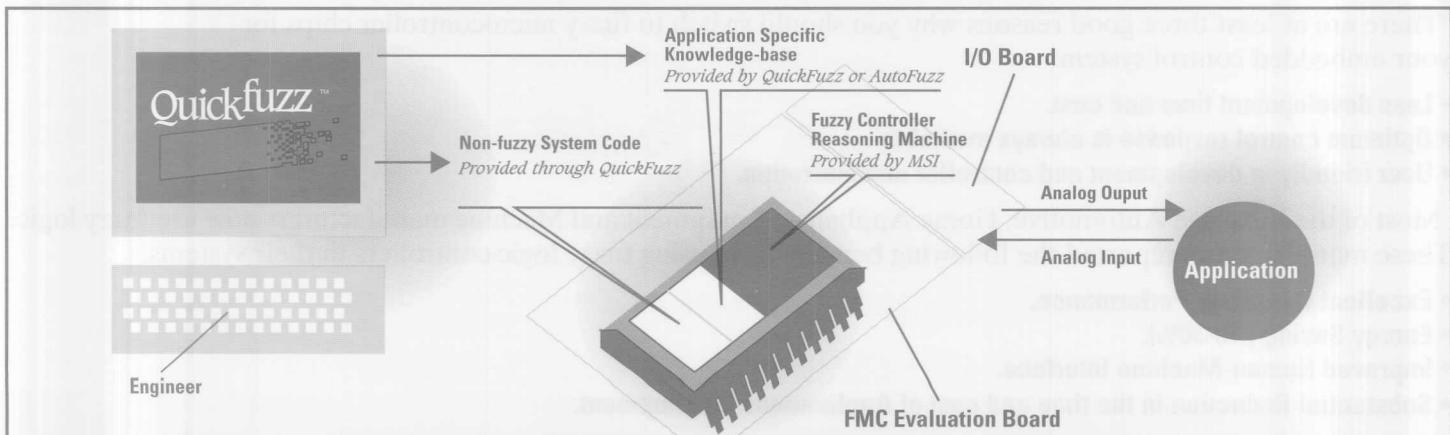


Figure 3. The Development Environment Using the QuickFuzz System to Customize FMC Chips.

MSI is in a unique position of supporting a number of Fuzzy Microcontroller Chips (FMC). The user is provided with a general-purpose microcontroller chip (MCU) already programmed with the advanced and real-time MSI fuzzy controller reasoning machine. The FMC requires only an application specific knowledge base to be programmed into the internal or external memory to be converted into a customized fuzzy controller for a particular application.

MSI offers its FMC using chips of such vendors as Motorola, Intel, NSC and many more. MSI produces these FMC by burning its advanced proprietary fuzzy controller reasoning algorithm into these chips. Table (1) gives some of the fuzzy controller chips that are supported by MSI in 1994.

Note: It is MSI policy to support any MCU chip proposed by the customer. This includes 4,8,16 and 32 bit chips.

Table 1. Fuzzy Microcontroller Chips Supported by MSI in 1994

FMC-M68HC11	Motorola M68HC11
FMC-M68HC05	Motorola M68HC05
FMC-M68HC08	Motorola M68HC08
FMC-NSC-COP8	NSC COP8 family
FMC-NSC-HPC16	NSC HPC16
FMC-I 8751	Intel I 8751 family
FMC-Z8	Zilog Z8 family

Q6. Why the Fuzzy Chip Instead of Directly Going to the Microcontroller Units (MCU)?

There are at least three good reasons why you should switch to fuzzy microcontroller chips for your embedded control system:

- Less development time and cost.**
- Optimum control response is always available.**
- User friendly in development and controller customization.**

Most of the Japanese Automotive, Home Appliance, Equipment and Machine manufacturers now use fuzzy logic. These manufacturers reported the following benefits from using fuzzy logic controllers in their systems:

- Excellent Operation Performance.**
- Energy Saving (10-30%).**
- Improved Human-Machine Interface.**
- Substantial Reduction in the time and cost of Applications Development.**

months. Most of this time will be spent on obtaining a proper algorithm to control your system and then on the software/firmware development to code this algorithm. This is a time consuming and a relatively expensive process.

The FMC provides a universal optimum control algorithm. It frees engineers from developing the control algorithms for your application. No costly software/firmware development will be required to develop the product.

Application development using standard (conventional) fuzzy logic usually takes 3-6 months and saves 30%-50% of the development cost. This is the case with using fuzzy controller development tools currently available in the world market.

MSI has developed automated design stations with **QuickFuzz**, **AutoFuzz** and **MultiFuzz** for fuzzy control applications development which allows the design team to develop the same application in just a few days. This results in an additional 30%-40% saving in the development of an intelligent fuzzy embedded control system. Table (2) below provides a comparison of the time and cost required for application development using MSI fuzzy technology, the existing fuzzy technology, and the traditional MCU solutions.

Item of Evaluation	MSI Fuzzy Solution	Standard Fuzzy Solution	Traditional MPU Solution
Average Time of Development	1-4 weeks	3-6 Months	12-18 Months
Average Cost of Development	Low	Medium	High

Table 2. A Comparison of the Development cost of Embedded Control Systems



Q8. How Can I Speed Up the Development of My Fuzzy Embedded Controller Board?

If you have an embedded controller board already installed and it is in operation, then you are only required to replace the current MCU chip with the FMC of the same vendor using the same board. No additional modifications are required.

If you have a new application and a new requirement, then greater flexibility is offered to implement an advanced fuzzy control and decision making system. A new board hosting the fuzzy controller chip has to be developed.

The new board can either be designed by your company, or you may choose to use ready made low cost boards developed by MSI. The **FlexFuzz** fuzzy controller series of boards offer a low-cost and ready embedded fuzzy controller suitable for your products and applications. These boards are designed using an open architecture concept and supported by an advanced application development expert system **MultiFuzz**. This solution has been specially developed by MSI to save your company time and cost in the design of new boards for the fuzzy controller. (Please refer to the MSI product list for additional information).



Q9. How Long Does It Take To Train My Engineers To Use Fuzzy Logic ?

Fuzzy is simple yet powerful. Engineers who have been involved in the embedded control application development will require only a few days to master the use of the Fuzzy Controller Design Station (FCDS). MSI offers one day seminars (twice a month) to prepare engineers to develop fuzzy control applications using the FCDS. MSI provides a hot-line for its customers to answer any questions and to respond to any help requests.

Q10. How is MSI Fuzzy Technology More Advanced than The Existing FuzzyTechnology?

The MSI fuzzy solution combines a set of advanced technologies developed to meet the functional and cost requirements of fuzzy control applications. Here are some of the innovations developed by MSI:

1. MSI has developed an advanced fuzzy controller reasoning machine, the CT-FLC series, which is located in its Fuzzy Microcontroller Chips (FMC). MSI fuzzy reasoning machine delivers the second generation of fuzzy controller chips which are running about 100-500 times faster than competitive fuzzy reasoning machines when the same MCU chip is employed. The new MSI reasoning machine also provides better resolution and control response. Figure (4) illustrates the time performance of MSI and existing fuzzy controllers. This time has been estimated for applications with various number of inputs/outputs using the 8 bit Motorola MCU chips, and the M68HC05 and it is valid for any other MCU chip.

The time required to run the standard fuzzy (competitive to MSI) grows *exponentially* as the number of inputs are increased. The running time of MSI fuzzy grows *linearly* and never exceeds 8 msec for sophisticated 4 inputs x 4 outputs applications. (Compare with the 1000 msec and more required by the existing fuzzy).

MSI provides real-time Fuzzy Controller Solutions for your applications.

The high performance of MSI fuzzy reasoning machines allow our customers to select a low-end FMC chip to develop their real-time applications. This saves 30%-50% of the cost of each fuzzy chip used in the product when compared to the competitive fuzzy controllers.

2. MSI has also developed advanced fuzzy knowledge base compression to reduce the memory size required by fuzzy controllers. An estimated 80% reduction in the memory size is obtained compared to the existing fuzzy controllers. *This reduction saves 20%-40% of the MCU cost on each chip.* Table (3) shows a comparison

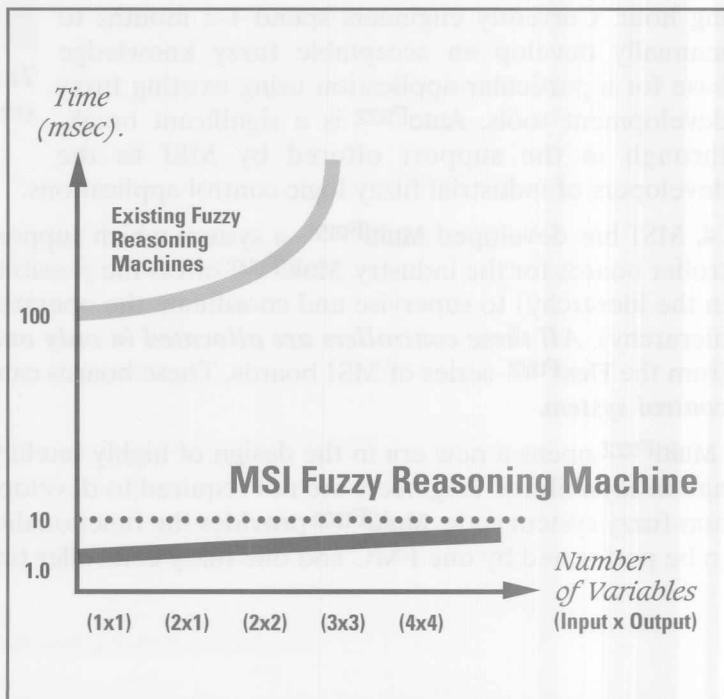


Figure 4. Comparison of the Time Performance of MSI and Standard Fuzzy Solutions Running on the same MCU chip

between the memory requirement of MSI and existing fuzzy solutions. The comparison has been made based on the use of Motorola MCU M68HC05, and is valid for any other MCU.

3. MSI has developed a completely automatic, knowledge base generation and tuning system under the name **AutoFuzz**. The **AutoFuzz** employs sophisticated on-line learning tools and optimization systems. It can generate the application specific knowledge base automatically in less than one working hour. Currently engineers spend 1-2 months to manually develop an acceptable fuzzy knowledge base for a particular application using existing fuzzy development tools. **AutoFuzz** is a significant breakthrough in the support offered by MSI to the developers of industrial fuzzy logic control applications.

4. MSI has developed **MultiFuzz** – a system which supports the design of highly intelligent embedded fuzzy controller boards for the industry. **MultiFuzz** offers the possibility to design a **Master Fuzzy Coordinator** (the first level in the hierarchy) to supervise and coordinate the operation of multiple fuzzy controllers (the second level of the hierarchy). **All these controllers are allocated in only one FMC chip** and require only one fuzzy controller board from the **FlexFuzz** series of MSI boards. These boards can be connected in a network to design a **fuzzy distributed control system**.

MultiFuzz opens a new era in the design of highly intelligent fuzzy control systems with optimization and coordination capabilities. Engineers are not required to develop any additional software routines to marry the fuzzy and non-fuzzy system code. **MultiFuzz** provides the functionality of the coordination, scheduling and other control tasks to be performed by one FMC and one fuzzy controller board.

The Application Input x Output Variables	The estimated memory required by MSI fuzzy controller chip (k byte)	The estimated memory required by existing fuzzy controller chip (k byte)
1 X 1	0.2	1.2
2 X 1	0.4	4
3 X 1	0.8	6
4 X 1	1.2	8
2 X 2	2	8
3 X 2	3	24
3 X 3	6	36
4 X 4	16	72

Table 3. A comparison of the memory required by MSI and standard fuzzy solutions



Q11. How Much Does MSI Fuzzy Controller Chip Solution Save me Compared to Existing Fuzzy Solutions ?

Two factors affect the total cost of the fuzzy embedded control system:

- **The cost of application development and fuzzy knowledge base generation.**
- **The cost of the fuzzy chip.**

The cost of fuzzy controller development using MSI FCDS using the automated application development systems **AutoFuzz** and **QuickFuzz** saves at least 80% compared to the cost of development using existing fuzzy development tools.

The cost of the MCU chip to run the fuzzy is determined by:

- **The MHz power/bit resolution of the chip.**
- **The internal memory of the chip.**

The standard (competitive to MSI) fuzzy solutions generally require extensive MHz power and memory size of the chip to meet the real-time application requirement. This leads to the selection of one of three possible solutions offered by the existing fuzzy (all are relatively equal in cost):

- **The use of one high performance MCU chip.**
- **The use of two low- end MCU chips.**
- **The use of a fuzzy ASIC chip together with a low performance MCU chip.**

The fuzzy logic developed by MSI requires substantially less memory (80%), MHz power(80%) and bit resolution than existing fuzzy logic. This translates into a great saving in the cost of the fuzzy controller chip.

MSI fuzzy allows customers to utilize a single low-end chip solution for most applications. MSI fuzzy technology saves about 30%-50% of the cost of each chip utilized in the product compared to existing fuzzy solutions.

MSI provides a wide range of products to support embedded control engineering development using fuzzy controllers. There are three categories of products:

- **Fuzzy Controller Chips.**
- **Development Stations and Systems.**
- **Embedded Fuzzy Controller Boards of "FlexFuzz" series.**

Each of these categories contains a variety of products to meet the customer's specific application requirements. Table (4) shows the products in these three categories.

2. MSI Services and Technical Support

MSI supports its customers by:

- Supplying the required quantity of fuzzy microcontroller chips (FMC) according to your requirements.
- Developing fuzzy controller applications according to your requirements. MSI will deliver a cost-effective fuzzy controller solution suitable for your system. MSI follows a policy to support a reasonable cost solution for customer applications development.
- Joint application development projects between MSI and its partners. Usually, MSI helps customers to the level of delivering the final product.
- Offering Training seminars, application notes and a hot-line for consultations. We provide all the necessary support to enable our customers to improve their competitiveness with the successful use of fuzzy logic in their systems.

Table 4. MSI Fuzzy Technology Products for Embedded Control Applications (1994)

Product Code	Product Designation
Fuzzy Controller Design Stations	
MSI offers many versions of its design stations to meet the requirements for applications development in embedded control, process control, as well as for training & simulation.	
FCDS-Emb-01	Fuzzy Controller Design Station With <i>QuickFuzz</i> For Embedded Control Applications
FCDS-Sim-01	Fuzzy Controller Design Station With <i>SimFuzz</i> For Training and Simulation
FCDS-Emb-02	Fuzzy Controller Design Station with <i>AutoFuzz</i> system for Automatic KB Generation and Tuning
FCDS-Emb-03	Fuzzy Controller Development Station with <i>MultiFuzz</i> system for the development of multiple Fuzzy Controller Systems With Coordination and Scheduling
Fuzzy Controller Chips	
FMC-M68HC11	Fuzzy Microcontroller Chips–Motorola M68HC11
FMC-M68HC05	Fuzzy Microcontroller Chips–Motorola M68HC05
FMC-M68HC08	Fuzzy Microcontroller Chips–Motorola M68HC08
FMC-NSC-COP8	Fuzzy Microcontroller Chips–NSC COP8 family
FMC-NSC-HPC16	Fuzzy Microcontroller Chips–NSC HPC16
FMC-I8751	Fuzzy Microcontroller Chips–Intel I 8751 family
FMC-Zilog-Z8	Fuzzy Microcontroller Chips–Zilog Z8 family
Evaluation Boards for Microcontroller Chips	
MSI-EVB-HC11	Fuzzy Evaluation Board for–Motorola MCU M68HC11
MSI-EVB-HC05	Fuzzy Evaluation Board for–Motorola MCU M68HC05
MSI-EVB-HC08	Fuzzy Evaluation Board for–Motorola MCU M68HC08
MSI-EVB-COP8	Fuzzy Evaluation Board for–NSC MCU COP8 family
MSI-EVB-HPC16	Fuzzy Evaluation Board for–NSC MCU HPC16
MSI-EVB-I8751	Fuzzy Evaluation Board for–Intel MCU I 8751 family
MSI-EVB-Z8	Fuzzy Evaluation Board for–Zilog MCU Z8
Fuzzy Controller Boards <i>FlexFuzz</i> Series	
MSI-FLCB <i>FlexFuzz</i> -HPC	Fuzzy Controller Board with NSC HPC FMC
MSI-FLCB <i>FlexFuzz</i> -HC11	Fuzzy Controller Board with Motorola HC11 FMC
MSI-FLCB <i>FlexFuzz</i> -I 8751	Fuzzy Controller Board with Intel I 8751 FMC
Input–Output Boards with Auto-Calibrations	
MSI-AIO-1.0	Modular Input/Output Boards (2x1) with Signal Conditioning and Facilities for Sensor and Signal Calibration



Q13. What is a FlexFuzz Controller Board and Why do you Need it ?

The **FlexFuzz** series of fuzzy controller boards are designed to provide customers with low-cost and highly-intelligent modular fuzzy controllers. These fuzzy controllers do not require any additional hardware or firmware to be developed for a specific application. The expert system **MultiFuzz** offers a great flexibility to configure the functionality and connectivity of these modular and low-cost fuzzy controller boards to meet specific application requirements. These fuzzy controllers can also be configured to create a very low cost distributed **fuzzy control system**.



Q14. What is a MultiFuzz System and How will it Help you to Develop Sophisticated Fuzzy Applications ?

MultiFuzz is a system which offers engineer-friendly tools to develop advanced fuzzy control applications requiring multi-level and multiple knowledge base fuzzy controllers. In particular, this system offers:

- **A manager fuzzy control (M-FLC) which coordinates the operation of multiple fuzzy logic controllers and generates an optimum trajectory for each fuzzy controller in terms of set points/time scheduling.**
- **Multiple fuzzy logic controllers with various knowledge bases to control many variables using only one fuzzy controller board of the series FlexFuzz.**
- **A fuzzy and PLC (F-PLC) controller which supports the functionality of fuzzy and industrial PLCs combined in one board.**
- **Configuration of multiple FlexFuzz fuzzy controllers in networking.**
- **Auto configuration of Input/Output channels and facilities for signal and sensor calibration.**
- **Interface to run AutoFuzz system for automatic knowledge base generation and tuning.**
- **User-friendly interface to develop safety and user communication manager.**
- **User-friendly system to test and monitor the fuzzy and F-PLC controller performance.**

Figure 5 shows the use of **MultiFuzz** to develop an advanced HVAC system using the fuzzy controller boards **FlexFuzz** series.

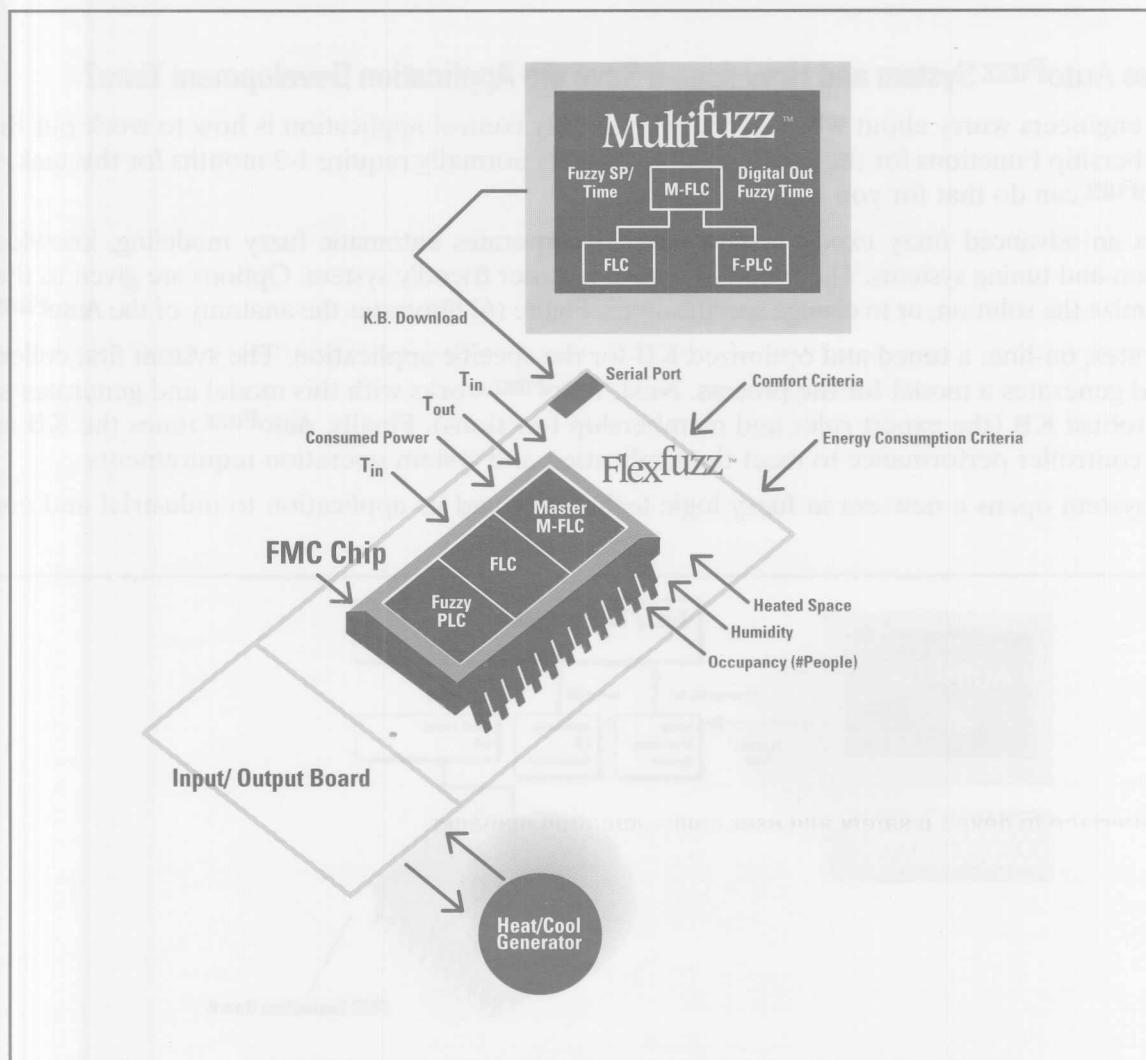


Figure 5. The Application of MultiFuzz to Design an Advanced HVAC System.

The first thing engineers worry about when developing a fuzzy control application is how to work out the Fuzzy Rules and Membership Functions for the application. Engineers normally require 1-2 months for this task. Not any more! MSI **AutoFuzz** can do that for you within minutes.

The **AutoFuzz** is an advanced fuzzy expert system which incorporates automatic fuzzy modeling, knowledge-base (“KB”) generation and tuning systems. The **AutoFuzz** system is a user friendly system. Options are given to the user to interfere, to optimize the solution, or to change specifications. Figure (6) illustrates the anatomy of the **AutoFuzz** system.

AutoFuzz generates, on-line, a tuned and optimized KB for the specific application. The system first collects some process data and generates a model for the process. Next, **AutoFuzz** works with this model and generates an initial but sufficiently robust KB (the expert rules and membership functions). Finally, **AutoFuzz** tunes the KB and optimizes the fuzzy controller performance to meet the application and system operation requirements.

MSI **AutoFuzz** system opens a new era in fuzzy logic technology and its application to industrial and embedded control systems.

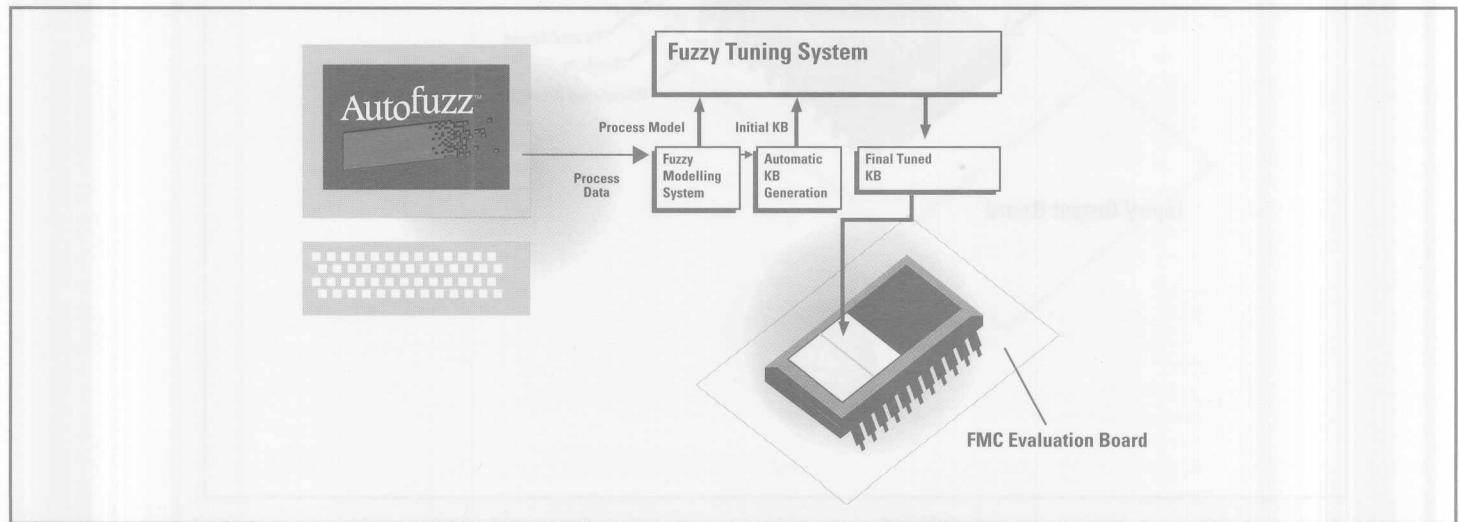


Figure 6. The MSI Fuzzy Controller development station with AutoFuzz System



Q16. Why Use MSI Fuzzy Technology ?

Fuzzy technology makes it easy for you to control processes and develop control solutions for your products. Before adopting any “fuzzy”, you must evaluate its practicality to your applications. Your decision is multi-dimensional, however, most importantly you must assess the **cost** and **performance**.

Many companies claim to have developed fuzzy logic controllers, yet very few have accomplished without making significant sacrifices on one of these issues. In fact, these drawbacks are inevitable for those trapped within the traditional concept of fuzzy logic using the compositional rule of inference (CRI). This always requires time-consuming max-min operations over fuzzy matrices to interpret the fuzzy rules. These matrices become into multi-dimensional for multi-variable systems. It is obvious to their users that either these controllers are slow, poor in quality of control, or beyond a reasonable price range. But, with MSI fuzzy technology, you will be saved from all of this!

Here at MSI (Mentalogic Systems Inc.), we proudly announce our success in developing state-of-the-art fuzzy logic controllers. After many years of R&D, we have been focusing on designing “**affordable, fast and optimal**” controllers. We have accomplished our goals with our proprietary CT-FLC, a brand new reasoning machine for Fuzzy Logic Controllers. This class of fuzzy controller has eliminated the drawbacks of the traditional methods, and ushered in a new generation of fuzzy control technology.

This is not yet the end of the story. To satisfy your requirements, MSI has developed a number of fuzzy logic solutions tailored for the embedded and process control industry. This includes a large selection of fuzzy microcontroller chips (FMC) using popular embedded microcontrollers and fuzzy logic controller boards of the **FlexFuzz** series. Excellent development systems with automatic-knowledge base generation **AutoFuzz** and application development expert systems, **QuickFuzz** and **MultiFuzz**, are available for both products and each comes with user-friendly software and reliable hardware.



Q17. What Else Can You Tell Me About MSI ?

Mentalogic Systems Inc. is a Canadian Company on the leading edge of fuzzy logic technology in North America and in the world. Our R&D team consists of five departments:

Embedded Control, Process Control, Learning Systems, Expert Systems Development and Microcontroller Chip Design.

Our R&D is supported by aggressive groups for Applications Development, Marketing and Sales.

MSI supports an active international role in fuzzy technology. Over the next two years MSI will open offices in Europe and Asia Pacific, while expanding in the USA.



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